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(54) VARIABLE DISPLACEMENT PUMPS AND MOTORS

(71) We, DOWTY TECHNICAL DEVELOPMENTS LIMITED, a British Company, of Brockhampton Park, Brockhampton, Cheltenham, do hereby declare the invention,

for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a variable-displacement pump and to a variable-displacement motor having a displacement adjusting servo-motor. A smoothly adjustable servo-motor is well-known and will enable infinitely-variable displacement adjustment of the pump or the motor to be obtained. For many purposes it is desirable to have one or more separate manually-operable controls whereby a preselected or any one of a number of preselected displacements may be readily obtained and it is the main object of the present invention to provide such an arrangement. A further object of the invention is to provide such a control means operable at a remote position having regard to the pump or motor.

The present invention broadly comprises a variable-displacement pump or a variable-displacement motor having a fluid-pressure-operated servo-motor capable of adjusting pump or motor displacement from one limit to another limit by the supply of fluid at pressure to or from a working volume of the servo-motor, a valve means actuatable by the servo-motor at a position corresponding to a selected displacement between the limits, and a selecting valve co-operable with said valve means, said selecting valve having two settings, in one of which the valve means is rendered capable of controlling the pressure in the working volume to arrest the movement of the servo-motor substantially in the selected position and in the other of which it is rendered incapable of so controlling the pressure.

[*Price 25p*]

A further feature of the invention comprises a variable-displacement pump or a variable-displacement motor having a hydraulically-operated servo-motor capable of moving to adjust the pump or the motor displacement by the supply of liquid to or from a working volume in the servo-motor under the control of a main selecting valve having two settings in one of which the working volume is fed with a restricted flow at pressure to urge the servo-motor to one displacement limit and in the other of which the working volume is connected to low pressure to facilitate servo-motor movement to the other displacement limit under a restoring force, an auxiliary valve means actuatable by the servo-motor at a position corresponding to a selected displacement between the limits, and an auxiliary selecting valve co-operable with the auxiliary valve means and having two settings in one of which the valve means provides a vent to a low pressure zone such that at the selected position when the main selecting valve is in said one position, a substantial pressure change in the working volume is caused to occur to the extent to arrest the servo-motor substantially in the selected position, and in the other of which the valve means is rendered incapable of carrying liquid flow.

By this invention, when the selecting valve is moved to the said one setting, it is capable of causing the servo-motor to select the selected displacement between the two displacement limits.

The servo-motor may be of the piston-and-cylinder type, and the valve may be a port in the servo cylinder itself, opened or closed by movement of the piston relative thereto at the position of the port.

Alternatively the valve means may be a valve structure, separate from the servo-motor and mechanically actuated thereby to open or close the port to the working vol-

ume at the particular pump or motor displacement intermediate the limits.

A plurality of valve means may be provided at differing displacements between the two limits, each valve means having a selecting valve associated therewith whereby the servo-motor may be stopped at the position of any one of the valve means by the appropriate selection of settings of the selecting valves.

The servo-motor may draw its actuating fluid from a supply of restricted flow rate and the action of the or a valve means may merely be to connect or dis-connect the restricted supply to or from a low pressure zone. For use with a variable-displacement pump, the delivery of the pump itself may supply fluid through a restrictor to form the supply of restricted flow rate provided that the range of adjustment between the said limits does not include zero pump displacement.

A relay valve may be provided movable in accordance with movement of the selecting valve for rendering the said valve means operative or in-operative.

The relay valve may comprise a relay piston slidable in a relay cylinder against spring loading, the relay cylinder including a plurality of ports connected to the servo cylinder ports, and the relay piston being adjustable against spring loading to selectively cover or uncover differing numbers of the ports by means of selective pressure adjustment thereof under the control of the selecting valve.

Two embodiments of the invention for use with a variable-displacement pump will now be particularly described with reference to the accompanying drawings, in which

Figure 1 is a diagrammatic illustration of the first embodiment, and

Figure 2 is a diagrammatic illustration of the second embodiment.

Referring initially to Figure 1, the variable-displacement pump 1 is of any kind in which displacement is variable by movement of a member such as the lever 2 and is also of the kind which will tend to move on its own towards the minimum displacement position. An example of such a pump is a swash-plate pump in which the angular setting of the swash-plate is adjustable to vary displacement. A piston-and-cylinder servo-motor 3 is connected to the lever 2 by means of a link 4. The servo-motor comprises a fixed cylinder 5 having a piston 6 slidable therein being connected to the link 4 by means of a connecting rod 7. The pump is arranged to draw liquid from a low pressure reservoir 8 and to deliver it to a delivery pipe 9 which may be connected to any suitable hydraulic load.

Within the cylinder 5 a stop 11 is provided against which the piston 6 engages to define the minimum displacement limit of the pump. Liquid at pressure from the delivery pipe 9 is connected through a restrictor 12 and pipe 13 to the right-hand end of the cylinder 5 which includes the stop 11. The pipe 13 is also connected by way of a selecting valve 14 to a pipe 15 returning to the reservoir 8.

The valve means comprises three spaced ports 16, 17 and 18 in the wall of the cylinder 5. The port 16 is connected through a second selecting valve 19 to the pipe 15 and the port 17 is connected through a third selecting valve 21 to the pipe 15. The port 18 is connected directly through a pipe 22 to the pipe 15 and a branch pipe 23 also connects the extreme left-hand end of the cylinder 5 to the pipe 15 at a position where it cannot be closed by the piston 6. The three selecting valves 14, 19 and 21 are each comprised by a simple manually-operable valve having open and closed positions.

In operation of the Figure 1 embodiment, the pump 1 is suitably driven and liquid is drawn from the reservoir 8 and delivered to the pipe 9 from whence it will pass to the load. Liquid at pressure also flows through the restrictor 12 to the right-hand end of cylinder 5. If minimum delivery flow only is required from the pump, the first control valve 14 is opened to reduce the pressure at the right-hand end of cylinder 5 to reservoir pressure. Then quite irrespectively of the positions of the valves 19 and 21, the piston 6 will remain in the minimum displacement position. If the pump is not capable on its own of moving to the minimum displacement position, then it may include a device such as a spring capable of exerting a constantly acting force tending to move the displacement to the minimum position. In order to obtain an increased flow rate from the pump, valve 14 is closed and valve 19 is opened. The pressure will then build up at the right-hand end of the cylinder 5 to urge the piston 6 to the left to increase pump displacement until the piston opens the port 16 to the working volume. At this point liquid will flow through the port 16 and the valve 19 to reservoir taking liquid from the working volume to the extent that the pressure remaining is just sufficient to maintain the pump at a displacement adjustment corresponding to the position of the port 16. Assume now that a further increase in delivery flow rate is required. The valve 19 is then closed and the valve 21 is opened. The servo piston will then travel up to the position where it just connects the port 17 to the working volume to the extent that liquid escaping from the working volume through the valve 21 reduces pressure so that the piston is just retained in position at the port 17 thus giving the required increased displacement. In

order to obtain maximum displacement the three valves 14, 19 and 21 are all closed and the piston 6 will then move to the position where the port 18 is connected to the working volume, flow being permitted to the extent that the pressure retained within the working volume is sufficient to hold the pump at its maximum displacement. The port 18 becomes effectively the maximum limit of pump displacement.

It will be apparent that the piston 6 can be arranged to adjust the pump to any of four particular displacement adjustments depending on the settings given to the three selecting valves 14, 19 and 21.

It will also be apparent that the valve means formed by the ports 16, 17 and 18 may be replaced by an auxiliary valve mechanically connected for movement with the servo piston 6.

Reference is now made to the second embodiment of the invention shown in Figure 2. The variable-displacement pump 31, which again is capable on its own of moving to the minimum displacement position, is connected for displacement adjustment through the medium of a lever 32. A servomotor comprising a servo-cylinder 33 and a servo piston 34 act through a pivoted link 35 to control the lever 32 for displacement adjustment. The pump 31 draws liquid through pipe 36 from a reservoir 37 and delivers such liquid to pipe 38 under pressure. The selecting valve assembly 39, which may be remotely placed relative to the pump 31, comprises four valve units 41, 42, 43 and 44 bolted together to form a complete assembly. The valves 41, 42 and 43 may each be of the kind shown in Patent Specification No. 1,289,882. The four valves 41, 42, 43 and 44 operate on the well-known open-centre principle and the delivery passage 38 passes through a passage 45 within the valve units. Each of the valve units includes an operating handle respectively 46, 47, 48 and 49. Each handle is capable of movement from the neutral position into a forward or a reverse position. When the handle is in its neutral position, the open-centre passage through the valve unit is in an open unrestricted condition. When a handle is moved to either a forward or a reverse position the open-centre passage is closed and is connected to the supply and return connections of a load. The valves 41 to 44 respectively are connected to loads 51, 52, 53 and 54 which for convenience are indicated as double-acting hydraulic jacks.

The valves 41, 42 and 43 each has an auxiliary open-centre passage 55 extending from the reservoir connection 36. The function of the auxiliary open-centre passage 55 is for control of the servomotor in a manner to be described.

The servo cylinder 33 and piston 34 are arranged as described in Patent Specification No. 1,276,657. In particular, the servo piston 34 is mounted in the servo cylinder 33 to enclose a working space 56 between the piston and a control unit 57 mounted in the servo cylinder. The control unit is fed with liquid from the pump delivery connection 38 into the passage 58 and includes structure which is responsive to the pressure of this liquid to control the axial movement of a control rod 59 which extends from the control unit into a bore 61 within the piston. The control rod is located by a loose pin and hole connection 62 within the piston to be capable of limited lost motion relative thereto, such limited lost motion adjusting the opening of a vent port 63 within rod 59 from the working space 56 to the interior of the pump casing which in turn is connected to the tank 37. Under normal conditions of operation the rod 59 will be urged to the left limit of its movement so that the port 63 is maintained closed. High pressure liquid from the connection 58 has access to the working space 56 through a restrictor 64 and the working pressure within working space 56 will then clearly depend on the leakage flow rate permitted from the working space 56.

To enable the selecting valve assembly 39 to be remotely located relative to the pump and servo-motor, a relay valve 65 is provided. This valve may be formed as shown in the same structure which accommodates a servo-motor or it may be separately formed. The relay valve comprises a relay cylinder 66 within which a relay piston is slidably mounted being urged to the right against a stop 68 by means of a compression spring 69 also within the cylinder. The right-hand end of cylinder 66 forms working space 60. Three ports 71, 72 and 73 open in axially spaced relation both in the servo cylinder 33 and into the relay cylinder 66. The minimum displacement position of the servo piston 34 as shown, i.e. completely to the right, corresponds with the minimum displacement position of the relay piston 67 also completely to the right. In these positions the servo piston 34 completely covers the ports 71, 72 and 73, but the relay piston leaves these ports completely uncovered. The space in relay cylinder 66 to the left of piston 67 is connected to reservoir through pipe 36. A passage 74, uncontrolled by piston 34 extends from working space 56 to the end of the auxiliary open-centre passage 55 in the selecting valve assembly remote from the pipe 36. The pipe 74 is also connected by means of a restrictor 75 into the cylinder 66 on the left of piston 67 and also by a restrictor 76 to the right-hand end of the cylinder 66. The restrictor 75 is closed by the piston 67 on initial movement from its

right-hand position. It will be seen that further movement of the relay piston 67 to the left will successively close the ports 71, 72 and 73. Three ports 77, 78 and 79 open into the cylinder 66 at a position to the right of the ports 71, 72 and 73 so as to be closed by piston 67 when in its right-hand position. The axial length of the piston 67 is such that when the piston moves to the left, it may occupy any of three controlling positions in which one of the ports 77, 78 or 79 are just opening to the working space 60. In these three positions, the left-hand edge of piston 67 stops short respectively of the ports 71, 72 and 73.

The port 77 connects to a pipe 81 through check valve 82 into the auxiliary open-centre passage 55 at a position between valve units 42 and 43. The port 78 connects to a pipe 83 through a check valve 84 to the auxiliary open-centre passage 55 at a position between valve units 41 and 42. The port 79 connects through a check valve 85 to the left-hand end of cylinder 66 for permanent connection to reservoir. The check valves 82, 84 and 85 are all arranged such as to permit flow only in a direction away from the working space 60.

In mounting the selecting valve assembly remotely from the pump, the pipes 74, 81, 83 and 86 may be quite small diameter pipes. The pipe 86 connects the auxiliary open-centre passage 55 back to the reservoir connection 36. The pipe 38 which leads to the open-centre passage 45 and the return flow pipe 87 connecting the open-centre passage 45 back to reservoir are both of substantial size since these will carry the full delivery flow from the pump. In operation, assume that it is desired to operate the load 54 which is a load requiring only a very small flow rate. The handle 49 is moved from its neutral position closing the open-centre passage 45 and directing pump delivery to the load 54. The minimum displacement position of the servo piston 34 as shown ensures the minimum delivery flow rate for operation of load 54. In this minimum displacement position liquid at delivery pressure enters the working space 56 of the servo through restrictor 64 and escapes through the passage 74. The passage 74 is formed by a long thin pipe which itself possesses a restrictive effect. Therefore leakage liquid leaving the working space 56 of the servo has two paths back to tank, the first being through restrictor 75 and the second being through pipe 74 and auxiliary open-centre passage 55. The combined effect of these two flows reduces the pressure in working space 56 to the extent that the servo piston 34 cannot move to increase pump stroke.

Assume now that it is desired to operate the load 53 and the handle 48 is moved from the neutral position, handle 49 then being moved back to the neutral position. Movement of handle 48 from the neutral position closes the main open-centre passage 45 and connects the load 53 to receive the main pump output. Movement of the handle 48 also closes the auxiliary open-centre passage 55 thus closing the flow through pipe 74. The leakage flow rate from the working space 56 is therefore reduced and the pressure in working space 56 will therefore rise urging the piston 34 to the left to increase pump displacement. The increase in pressure in working space 56 is also accompanied by an increase in pressure in the pipe 74 which fed through restrictor 76 into working space 60 will raise pressure to move relay piston 67 to the left against spring load 69. The relay piston will move until port 77 opens and in this position restrictor 75 will be closed. At the opening of port 77, liquid will be vented from working space 60 through pipe 81 and auxiliary open-centre passage 55 to drain. The opening of port 77 will thus be automatically adjusting to a position where port 77 is opened only to the extent to maintain a sufficient pressure in working space 60 to balance the load of spring 69. Closure of restrictor 75 will cause further rise of pressure in working space 56 to urge the piston 34 further to the left to uncover port 71. Further leakage flow will take place through port 71 to reduce pressure in working space 56 to the extent that piston 34 will be located accurately in a position where port 71 is just opened. The delivery flow rate from the pump through the load 53 will then be in accordance with the displacement selected by the new position for servo piston 34.

Assume now that it is desired to operate the load 52 which requires a greater flow rate than the load 53. The handle 48 is put into its neutral position and the handle 47 is moved from its neutral position to close the open-centre passage 45 in valve unit 42 to connect the pump delivery to the load 52. Movement of the handle 47 will also close the auxiliary open-centre passage in valve unit 42 so that flow is prevented through both of the long thin pipes 74 and 81. Leakage is thus prevented through both these pipes and the pressure in working space 60 will rise to move relay piston 67 to the left so as just to open port 78 through which liquid may escape to drain. The opening is automatically adjusted so that the reduced pressure in working space 60 just balances the load of spring 69. At this position for the piston 67, the restrictor 75 and port 71 are closed, ports 72 and 73 being open. The closure of port 71 will cause pressure to rise in working space 56 which will urge servo piston 34 to the left to increase pump delivery. Movement to

the left will occur until the piston starts to open the port 72 and leakage flow through this port to drain will then establish a reduced pressure in working space 56 to balance the load on the servo piston 34.

Assume now that it is desired to operate the load 51 which requires maximum delivery from the pump. The handle 47 is replaced to neutral and the handle 46 is moved from neutral closing the main open-centre passage 45 in the valve unit 41 and thus connecting pump delivery to the load 51. Movement of handle 46 will also close the auxiliary open-centre passage 55 thus preventing leakage flow through any of the pipes 74, 81 and 83. The pressure in working space 60 will therefore rise causing piston 67 to move to the left until port 79 is opened slightly. The leakage flow through port 79 will reduce pressure in working space 60 to the extent to balance the load of spring 69. At this position of the relay piston 67, restrictor 75 and ports 71 and 72 are closed. The pressure in working space 56 will therefore rise causing servo piston 34 to move to increase pump displacement, such movement taking place until piston 34 begins to open the port 73. The leakage flow through port 73 will then reduce pressure in working space 56 to the extent that the servo piston will be located at the maximum displacement limit.

It will be seen that the use of the relay valve enables control of the servo piston 34 to be obtained by virtue of controlled leakage from the working space 56, such leakage whilst being small in comparison with pump delivery flow rates, nevertheless, itself being sufficiently substantial as to cause large pressure drops if it were to flow through the thin pipes 74, 81, 83 or 86. The relay valve 65 requires a considerably smaller leakage flow rate to adjust its position, and thus the servo piston 34 and the leakage flow control of the relay valve may be accomplished by the selecting valve assembly 39 through the use of the long thin pipes 74, 81, 83 and 86.

Whilst Figure 2 illustrates the use of the open-centre type of selecting valve in conjunction with stepped adjustment of the servo piston and the use of a relay valve, it will be appreciated that within the broad scope of the present invention the relay valve 65 could be omitted and the pipes 81 and 83 could be connected directly to the ports 71 and 72 to directly control pressures in the working space 56. However, in this case, the selecting valve assembly could not be remotely located since the restrictive effects of the pipes 74, 81, 83 and 86 would prevent any substantial adjustment of pressure in the working space 56 when the piston 34 uncovered the ports 71 and 72.

The control unit 57 may operate in any of the manners disclosed in Patent Specification No. 1,276,657, the control effected thereby being a maximum limit control in which case the movement of the servo piston 34 to increase displacement would open the vent port 63 if the delivery of the pump were greater than that demanded by the control unit 57. If the pump delivery is less than that dictated by the control unit 57 the movement of the valve rod 59 in the piston 34 would be to the limit of the lost motion 62 so as to close the vent port 63. Assume for example that the control unit 57 is intended to control the pump so as to provide a substantially constant maximum driving torque. If the driving torque for the pump tends to rise above this maximum value, then the servo piston 34 would tend to move relative to the control rod 59 to open the vent 63 and thus to overridingly reduce pressure in the working space 56 so that the maximum driving torque could not be exceeded.

WHAT WE CLAIM IS:—

1. A variable-displacement pump or a variable-displacement motor having a fluid-pressure-operated servo-motor capable of adjusting pump or motor displacement from one limit to another limit by the supply of fluid at pressure to or from a working volume of the servo-motor, a valve means actuatable by the servo-motor at a position corresponding to a selected displacement between the limits, and a selecting valve cooperable with the said valve means, said selecting valve having two settings, in one of which the valve means is rendered capable of controlling the pressure in the working volume to arrest movement of the servo-motor substantially in the selected position, and in the other of which it is rendered incapable of controlling the pressure.

2. A variable-displacement pump or a variable-displacement motor having a hydraulically-operated servo-motor capable of moving to adjust the pump or the motor displacement by the supply of liquid to or from a working volume in the servo-motor under the control of a main selecting valve having two settings in one of which the working volume is fed with a restricted flow at pressure to urge the servo-motor to one displacement limit and in the other of which the working volume is connected to low pressure to facilitate servo-motor movement to the other displacement limiter under a restoring force, an auxiliary valve means actuatable by the servo-motor at a position corresponding to a selected displacement between the limits, and an auxiliary selecting valve cooperable with the auxiliary valve means and having two settings in one of which the valve means provides a vent to a low pressure zone such that at the selected position when the main selecting valve is in said one position,

a substantial pressure change in the working volume is caused to occur to the extent to arrest the servo-motor substantially in the selected position, and in the other of which the valve means is rendered incapable of carrying liquid flow.

3. A variable-displacement pump or motor as claimed in Claim 1 or Claim 2, wherein the servo-motor is of the piston-and-cylinder type, and the valve means is a port in the cylinder itself opened or closed by movement of the piston relative thereto at the position of the port.

4. A variable-displacement pump or motor as claimed in any preceding claim, including a plurality of valve means at spaced displacement positions between the two limits, each valve means having a selecting valve associated therewith, whereby the servo-motor may be stopped at the position of any one of the valve means by appropriate selection of the settings of the selecting valves.

5. A variable-displacement pump or motor as claimed in any preceding claim, wherein the working volume is fed with liquid at pressure from a supply of restricted flow rate and the action of the valve means is to connect or dis-connect the restricted supply to or from a low pressure zone in accordance with movement of the servo-motor.

6. A variable-displacement pump as claimed in Claim 5, wherein the delivery of the pump itself, fed through a restrictor, forms the said supply of restricted flow rate for feeding to the said working space.

7. A variable-displacement pump or motor as claimed in any preceding claim, including a relay valve movable in accordance with movement of the selecting valve for rendering said valve means operative or inoperative.

8. A variable-displacement pump or motor as claimed in Claims 3, 4 and 7 wherein the relay valve comprises a relay piston slidable in a relay cylinder against spring loading, the relay cylinder includes a plurality of ports connected to the servo cylinder ports, and the relay piston is adjustable against spring loading, to selectively connect and dis-connect differing numbers of the ports by means of selective pressure adjustment under control of the selecting valve.

9. A variable-displacement pump or motor as claimed in Claim 8, wherein the selective pressure adjustment means includes a plurality of selecting ports in said relay cylinder uncovered progressively during movement of said relay piston to connect to a working space in said relay cylinder, a restricted supply of pressure liquid connected to said relay working space, and said selecting valve comprises a plurality of manually operable valves for selectively connecting said selecting ports to drain, the relay piston moving to a position to partially close a selecting port connected to drain by a manually operable valve in order to adjust pressure in the relay working space to meet the spring load at that position.

10. A variable-displacement pump or motor as claimed in Claim 9, wherein the manually-operable valves are connected in series in a passage extending to drain and the selecting ports are connected to said passage at positions intermediate said manually-operable valves.

11. A variable-displacement pump or motor as claimed in Claim 10, wherein said restricted supply of pressure liquid includes two fixed restrictors in series between the relay working space and a pressure source and said passage connects at one end to the junction of the two restrictors.

12. A variable-displacement pump as claimed in Claim 11, wherein said manually-operable valves are each connected for joint operation with a main open-centre valve the open-centre valves being connected in series in a flow passage carrying the pump delivery, operation of any manually-operable valve to select a particular displacement setting for the pump also closing the associated open-centre valve to connect pump delivery to a particular load.

13. A variable-displacement pump as claimed in Claim 12, wherein one limit of pump displacement adjustment comprises minimum displacement and including one open-centre valve connected to a manually-operable valve but separately operable to close the flow passage and to connect pump delivery at minimum displacement to a particular load.

14. A variable-displacement pump substantially as particularly described with reference to Figure 1 of the accompanying drawings.

15. A variable displacement pump substantially as particularly described with reference to Figure 2 of the accompanying drawings.

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1344623 COMPLETE SPECIFICATION
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Sheet 1

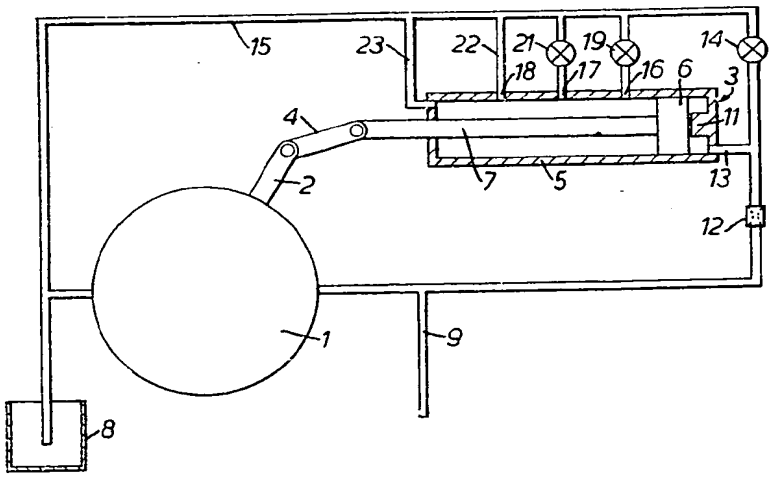

FIG. 1.

1344623 COMPLETE SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 2

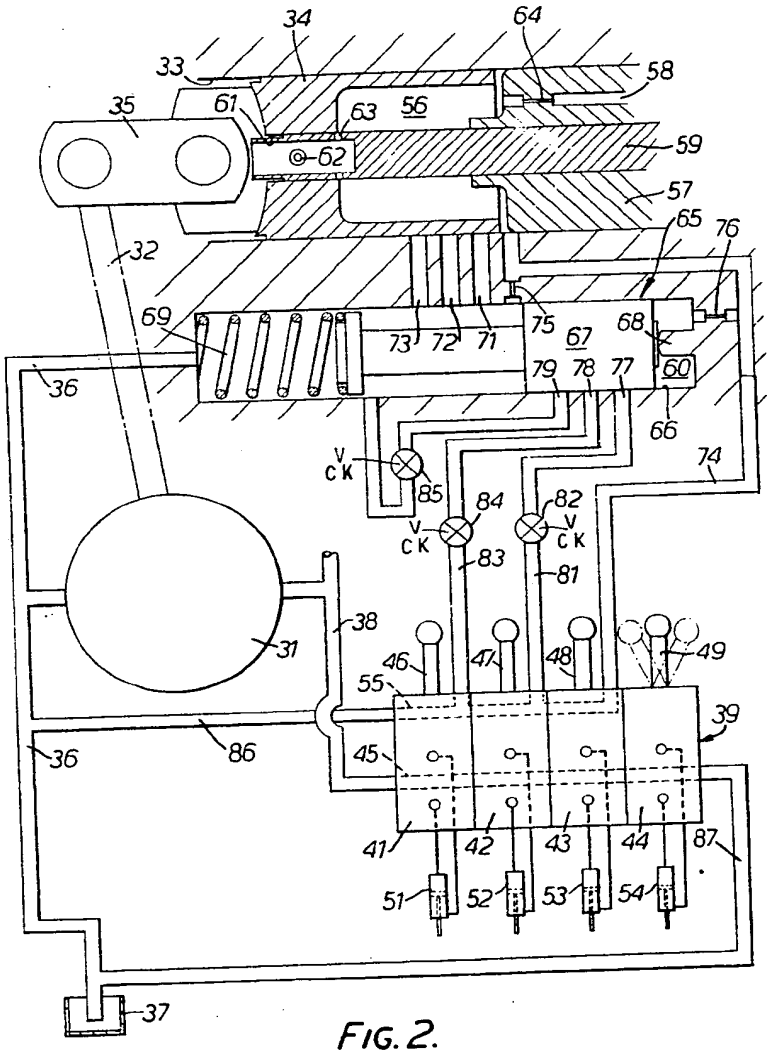

FIG. 2.